

A PORTABLE ION-ENERGY DIAGNOSTIC FOR TRANSFORMATIVE ARPA-E FUSION R&D

FUSION Diagnostics: First Annual Review (Virtual)
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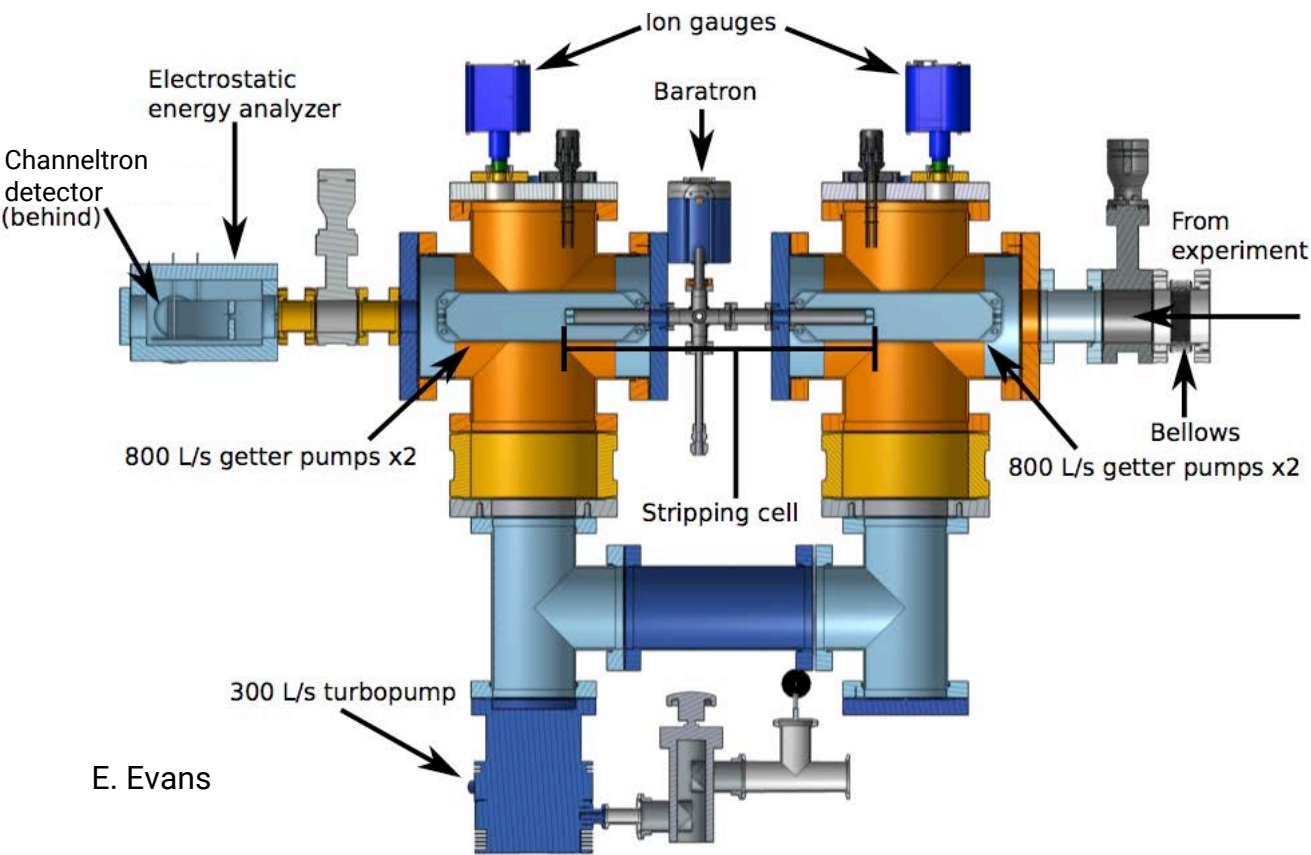


U.S. DEPARTMENT OF
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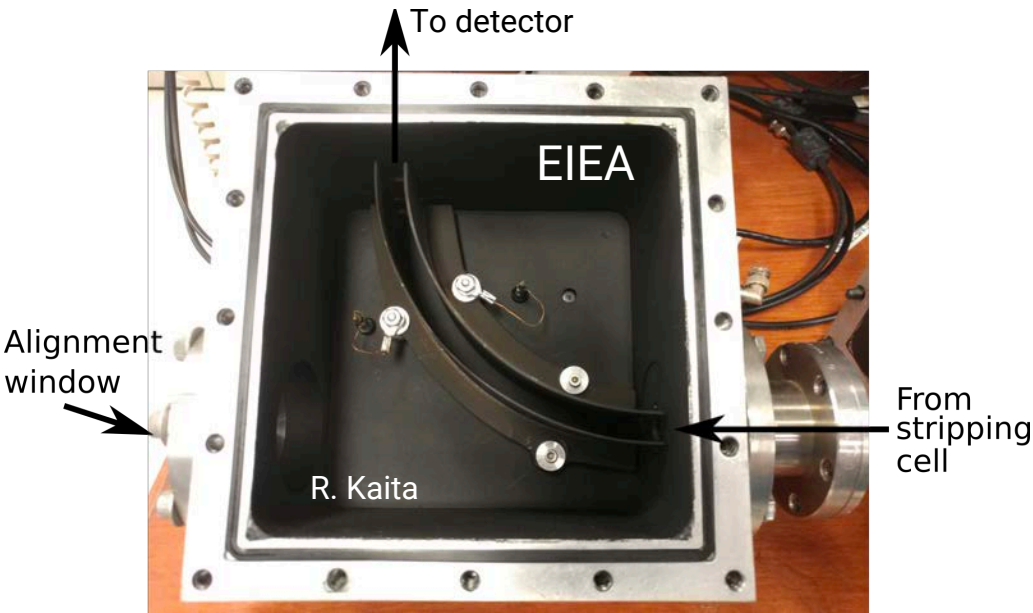
Team members and roles

- ▶ S.A. Cohen, PI
 - Set program & schedule
 - Operate PFRC-2
- ▶ B. Berlinger, Lead technician
 - Assemble & install diagnostic
- ▶ T. Provost, Vacuum specialist
 - Test vacuum integrity
- ▶ E. Evans, Graduate student
- ▶ Graduate student
 - Data collection & analysis system
 - Calibrate diagnostic
 - Operate diagnostic
 - Analyze data
- ▶ E. Kolemen, co-PI
 - AI planning of PFRC-2 runs
 - AI real-time PFRC-2 controls
- ▶ PSS scientist
 - Data analysis
- ▶ B. Koel
 - Provide ion gun for calibration

Stripping-cell Electrostatic Ion-energy Analyzer:



Metric	State of the Art	Proposed
Ion energy range (eV)	to 500 keV	To 3 keV
Time resolution (ms)	1	0.1
Spatial resolution (cm)	5	1
Energy Resolution ($\Delta E/E$)	<0.01	0.1
Mass (kg)	500	100
Volume (m ³)	5	1
Plasma density (cm ⁻³)	5x10 ¹⁴	2x10 ¹³



Robust and portable

Technology Summary: innovations

- Reduce size and mass of E_i diagnostic using modern vacuum equipment and on-board computer controls.
- Reduce perturbations to ARPA-E research devices with improved design.
- Use modern data algorithms and accelerate data processing to allow feedback control of plasma.

Methodology

- Portable gold-standard technique: Stripping cell + electrostatic ion energy analyzer.
- Ion energy range (100-3000 eV) and spatial and temporal resolutions set for ARPA-E MFE facilities.

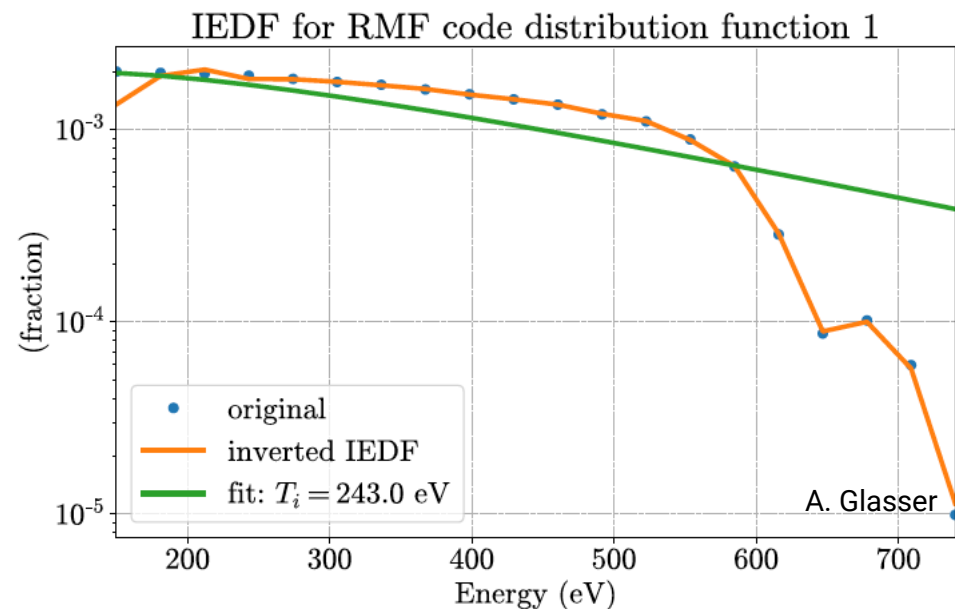
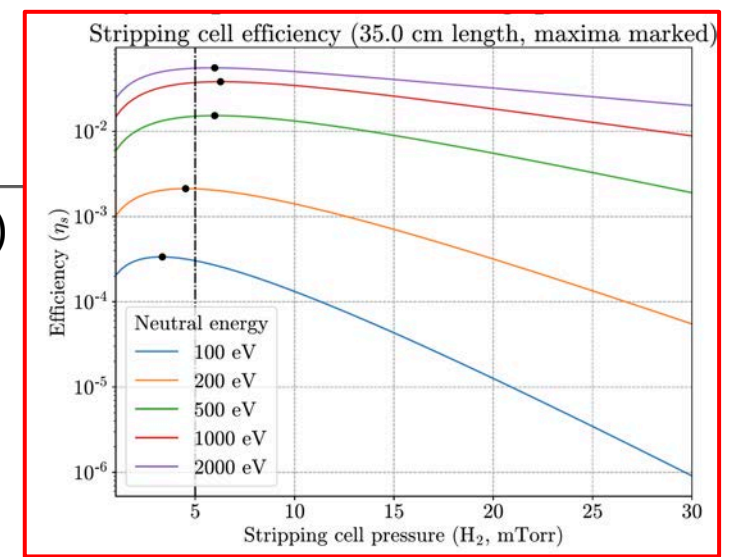


Deployment: PFRC-2 (Installation ~May 15)

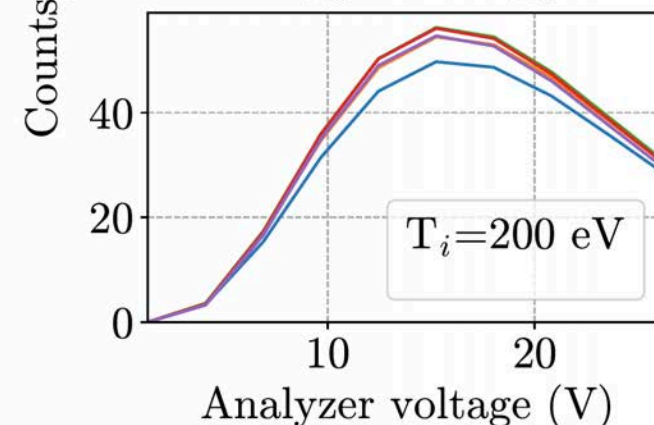
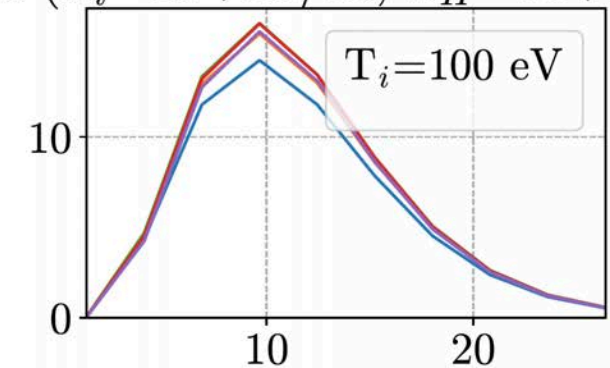
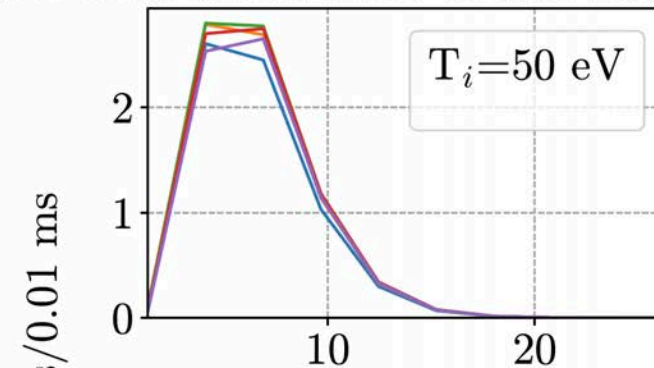
$\lambda_{e-H} \sim 25 \text{ cm @ } 100 \text{ eV, } 1e13/\text{cc (ionization)}$

Goal

- ▶ Test whether RMF_0 heats ions when $\omega_{\text{RMF}} < 2 \omega_{\text{ci}}$
- ▶ Contingent upon INFUSE (or other) funding for PFRC-2 operations



SC-IEA simulated count rates ($n_i = 1e+13/\text{cc}$, $n_H = 3e+10/\text{cc}$)



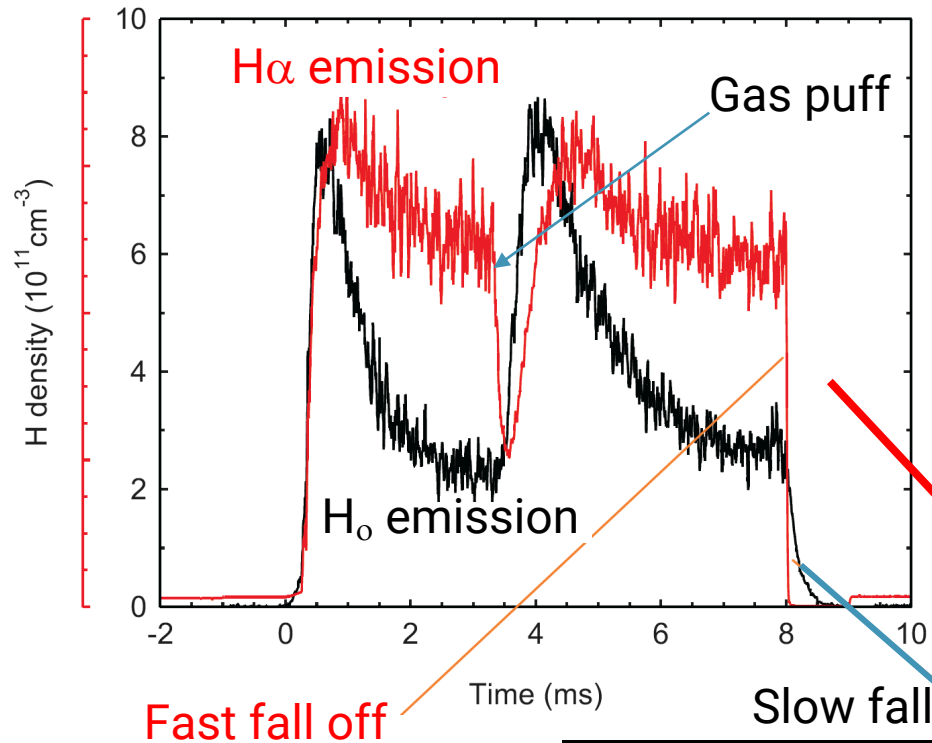
Gas cell pressure

- 3 mTorr
- 4 mTorr
- 5 mTorr
- 6 mTorr
- 7 mTorr

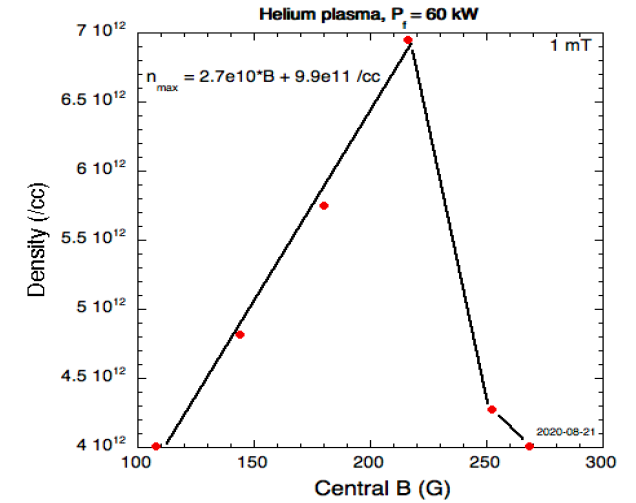
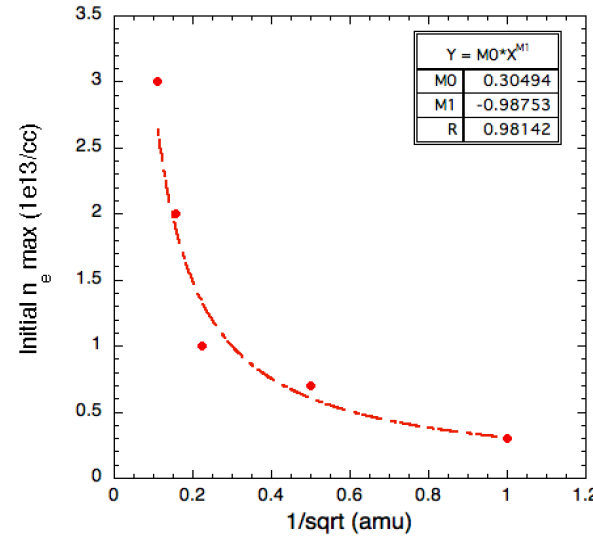
Preparatory measurements: H⁰ density and n_e in PFRC-2

► H⁰ via TALIF (A. Dogariu, PU-MAE)

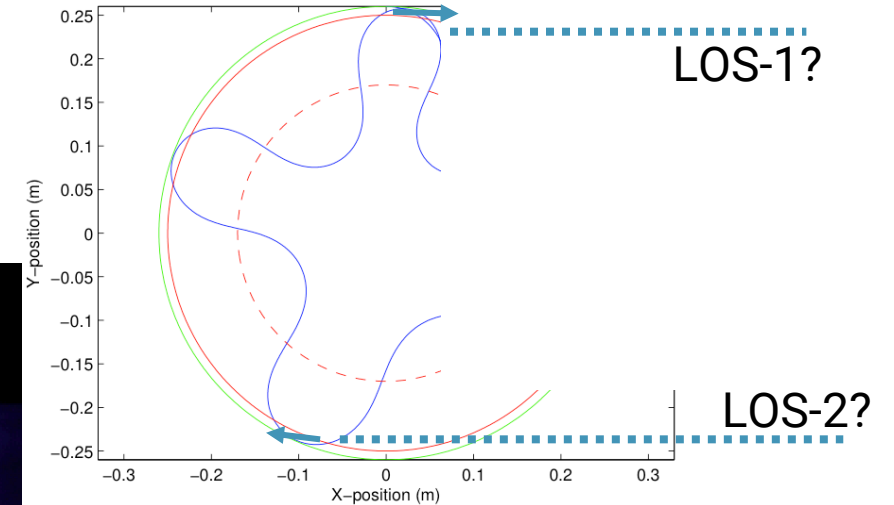
81 kW pulsed, H₂ puffing



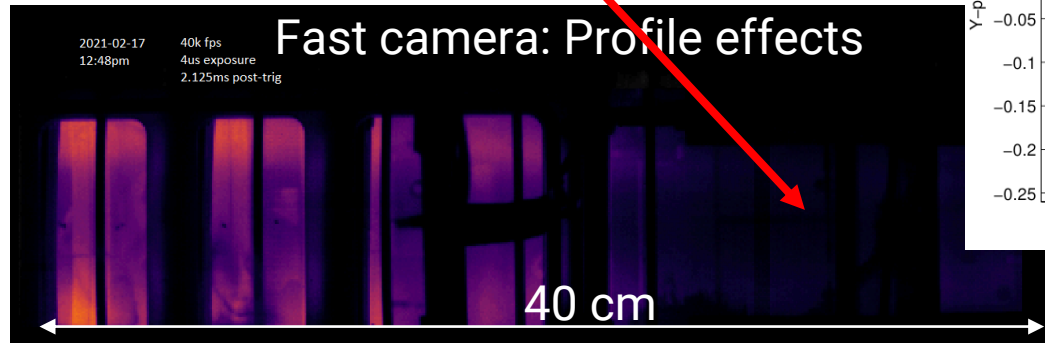
n_e (lower limit) via 170 GHz interferometer



@ z = 31 cm



Fast camera: Profile effects



Synthetic diagnostic?

Future plans

Fusion research

- Install & operate on PFRC-2
- Install & operate on HIT-SI
- Divertor diagnostic (MIT, NSTX, DIII-D...)
- Ion/neutral energies in detached divertor plasmas

Other possible applications

- Plasma processing
 - Role of energetic ions in etching
 - Formation/role of energetic neutrals during sputtering
- Spacecraft propulsion
 - Quantifying propellants: atomic vs molecular
 - Detachment of propellant from plasma rocket engines